

# *Water Reuse*

## *Microbiological Issues & Safety*

*Use it Again, America!*



***Is it Safe?***

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# Overview

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- **Concepts**
- **Guidelines & Standards**
- **Pathogen Data**
- **Track Record**

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**\* in USA or elsewhere where using  
adequate treatment & disinfection.**

**No Disease!!!**

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Feecal



Oral

# Infection Disease Mortality

# Log Removals

<b>1 Log</b>	<b>90%</b>
<b>2 Log</b>	<b>99%</b>
<b>3 Log</b>	<b>99.9%</b>

$$\text{Log Removal} = \text{Log}(C_{\text{in}}) - \text{Log}(C_{\text{out}})$$

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# Indicator Organisms

## ■ Coliforms (Total & Fecal)

- ◆ E. coli
- ◆ Enterococcus
- ◆ Clostridium
- ◆ Bacteriophage
- ◆ Others



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# Indicator Organisms

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- **Wide Range of Pathogens**
- **Available Indicator Organisms**
- **No “Optimal Indicator”**

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# Fecal Coliforms

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- **Bacteria**
- **“Indicator Organism”**
- **Water Standards**
- **Disinfection Standards**

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# Untreated Wastewater

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**10,000,000 Fecal Coli. / 100 mL**

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# 1,000 Fecal Coli. / 100 mL

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- **WHO Guidelines**
- **Irrigation of Edible Food Crops**

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# 200 Fecal Coli. / 100 mL

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- Treated Wastewater
  - ◆ “Basic Disinfection”
- Stream Standard
- Bathing Beaches
- 99.998 % Removal

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# Bathing Beaches



- For 200 FC/100 mL
- Risk of Illness
  - ◆ Per Swimming Occasion
- Saltwater
  - ◆ 19 illnesses per 1,000 Swimmers
- Fresh Water
  - ◆ 8 illnesses per 1,000 Swimmers

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# 200 Fecal Coli. / 100 mL

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- **Colorado Springs**
  - ◆ **Irrigation of Public Parks**
- **WHO Guidelines**
  - ◆ **Public Access Areas**

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# Drinking Water Standard

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■ **Total Coliform < Detection**

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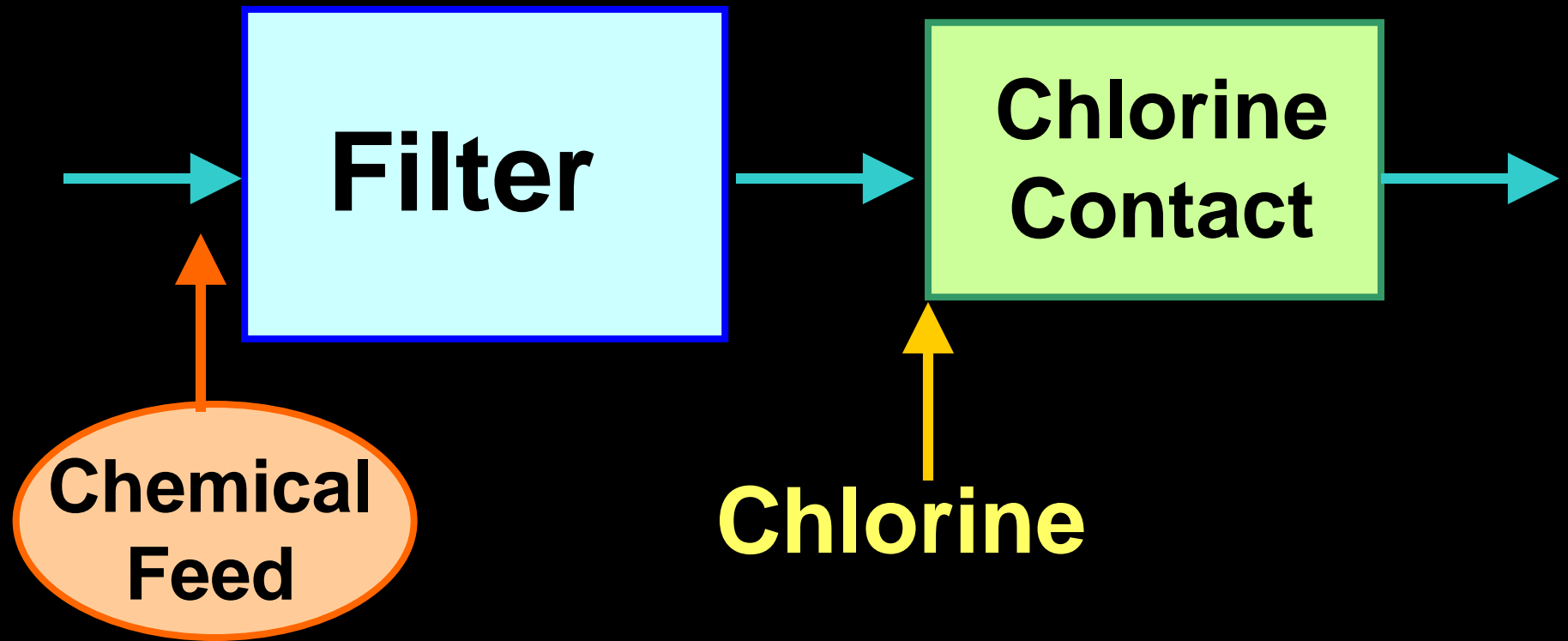
# Ground Water Standard

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- Potable Water
  - ◆ Without Disinfection
- 4 Total Coli. / 100 mL

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# High-Level Disinfection



# Florida's Requirements

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- **Fecal Coliforms**
  - ◆ **75 % Below Detection**
  - ◆ **Maximum 25 / 100 mL**
- **Total Suspended Solids (TSS)**
  - ◆ **Maximum < 5 mg/L**
- **Total Chlorine Residual**
  - ◆ **Minimum 1.0 mg/L**

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# Basis of Florida's Requirements

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- **Experimental Work**
- **Dr. Flora Mae Wellings  
(State Virologist)**
- **Virus < Detection**
  - ◆ **Fecal Coliforms < Detection**
  - ◆ **TSS < 5 mg/L**
  - ◆ **Chlorine > 1 mg/L**

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# Florida Operational Data

Statistic	TSS	Turbidity	Cl <sub>2</sub>
25%	1.0	0.6	2.8
50%	1.0	0.8	4.5
75%	1.6	1.3	5.0

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# California's Requirements

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- **Total Coliforms**
  - ◆ **Median  $< 2.2$  / 100 mL**
  - ◆ **Maximum 23 / 100 mL**
- **Turbidity**
  - ◆ **Average  $< 2$  NTU**
- **Total Chlorine Residual**
  - ◆ **CT  $> 450$  min-mg/L**

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# Basis of California's Requirements

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- **Pomona Virus Study**
  - ◆ **Full-Scale WWTP**
  - ◆ **Underloaded**
  - ◆ **Virus < Detection**

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# EPA's Guidelines

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- **Fecal Coliforms**
  - ◆ **50 % Below Detection**
  - ◆ **Maximum 14 / 100 mL**
- **TSS < 5 mg/L**
- **Turbidity < 2 NTU (average)**
- **Total Chlorine Residual**
  - ◆ **Minimum 1.0 mg/L**

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# Surface Water Standards

Class	Use	Standard
I	Water Supply	200 FC/100 mL
II	Shellfish	14 FC/100 mL
III	Recreation <input checked="" type="checkbox"/>	200 FC/100 mL
IV	Agriculture <input checked="" type="checkbox"/>	No Standard

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# Pathogens of Concern

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- Bacteria
- Virus
- Protozoa
- Helminthes

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# Bacteria

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- **Conventional Wisdom:**
  - ◆ **Normal Disinfection Processes do a Pretty Darn Good Job.**
  - ◆ **Pose Little Concern.**

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# Helminthes

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- **Conventional Wisdom:**
  - ◆ **Big & Clunky.**
  - ◆ **Removed by Clarification.**
  - ◆ **Won't See Them After Filter.**
  - ◆ **Pose Very Little Concern.**

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# Virus

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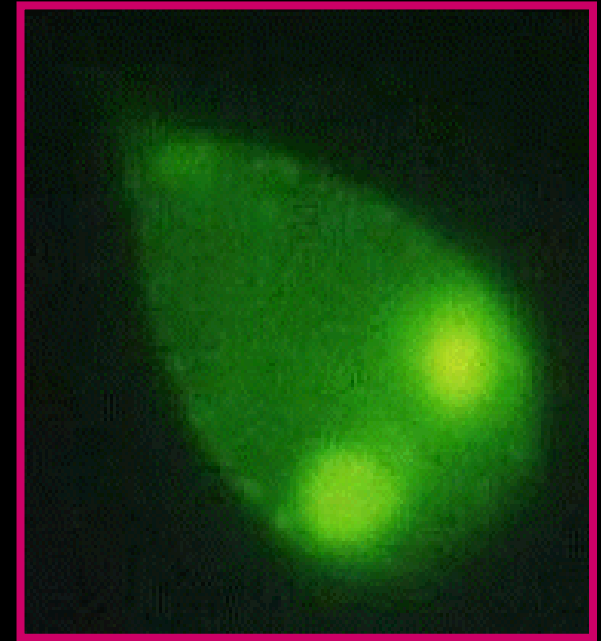
## ■ Conventional Wisdom:

- ◆ Small.
- ◆ Wide Range of Viruses.
- ◆ Resistant to Disinfection.
- ◆ Key Reuse Issue.
- ◆ Couple Filter with Disinfection.
- ◆ Can Effectively Control Viruses.

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# Giardia

- Discovered 1681
- Fecal / Oral Route
- Forms Cysts
- Reservoir
  - ◆ Humans
  - ◆ Beavers
  - ◆ Others



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# Cryptosporidium

- Discovered 1907
- Human Pathogen - 1976
- Fecal / Oral Route
- Forms Oocysts
- Reservoir
  - ◆ Humans
  - ◆ Over 40 Mammals



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# Untreated Wastewater (# / 100 L)

Organism	% Positive	Average
Virus	100	1,030
Crypto	67	1,460
Giardia	100	6,890
Helminths	33	1,650

**St. Petersburg, FL**

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# Reclaimed Water (# / 100 L)

Organism	% Pos.	Aver.	Max.
Virus	8	0.01	0.13
Crypto	17	0.75	5.35
Giardia	25	0.49	3.3
Helminth	0	--	--

**St. Petersburg, FL**

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# Log Removals

Organism	Filter	Plant
Virus	0.8	5.0
Crypto	1.7	3.3
Giardia	2.0	4.1

**St. Petersburg, FL**

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# Monterey County, CA



Organism	Untreat	Treated
Crypto (100 L)	7,400	ND
Giardia (100 L)	1,040,000	6
Cyclospora (100 L)	4,700	ND
E. Coli 0157:H7 (100mL)	ND	ND
Legionella (100 mL)	ND	ND
Salmonella (100 mL)	5	ND

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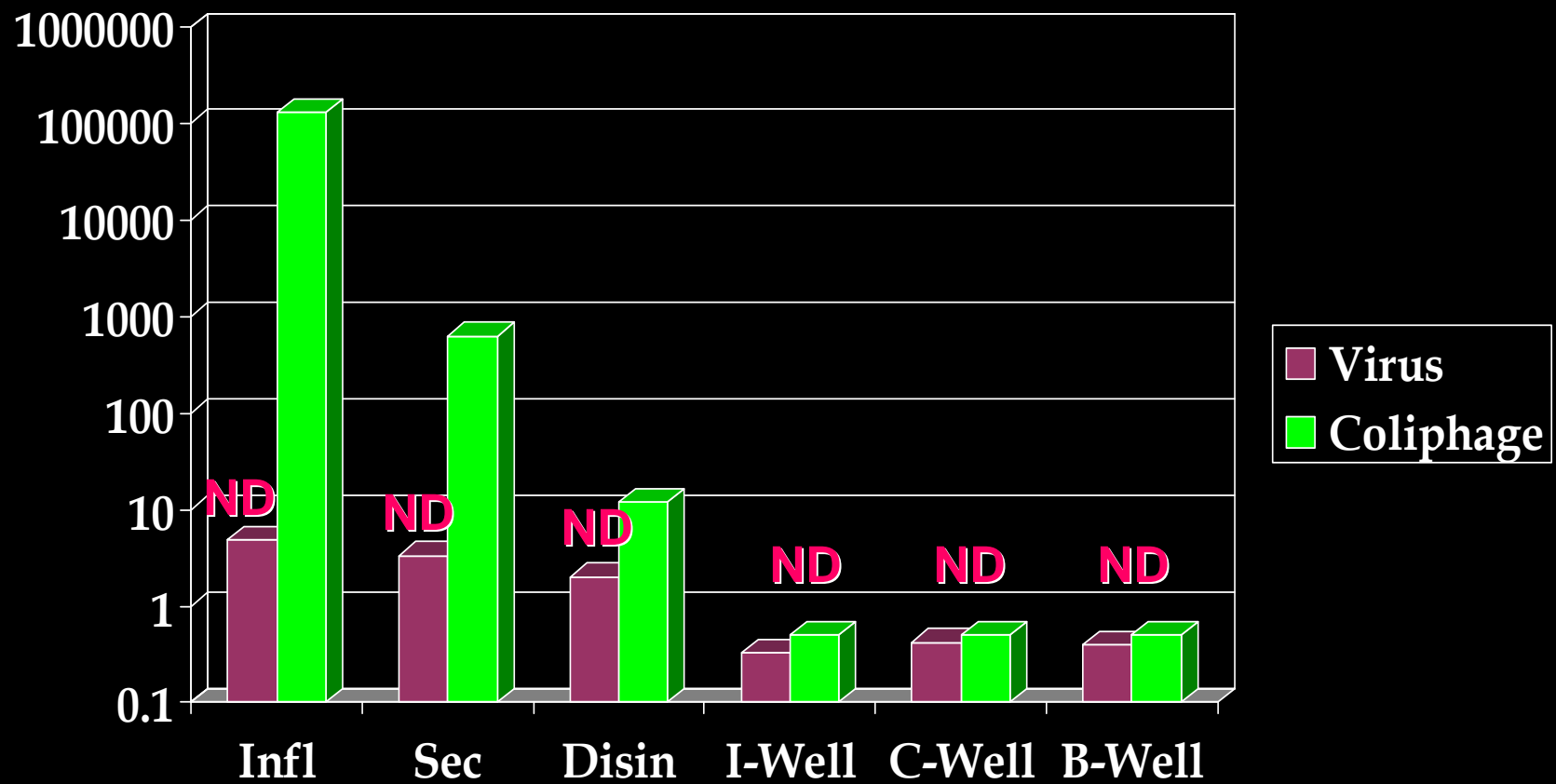
# RIB Pathogen Study

- **RIB in Central Florida**
- **WWTP**
  - ◆ **Secondary Treatment**
  - ◆ **Does not Nitrify**
  - ◆ **Basic Disinfection**
  - ◆ **200 FC/100 mL**
  - ◆ **No Filters**



# Virus (#/100L)

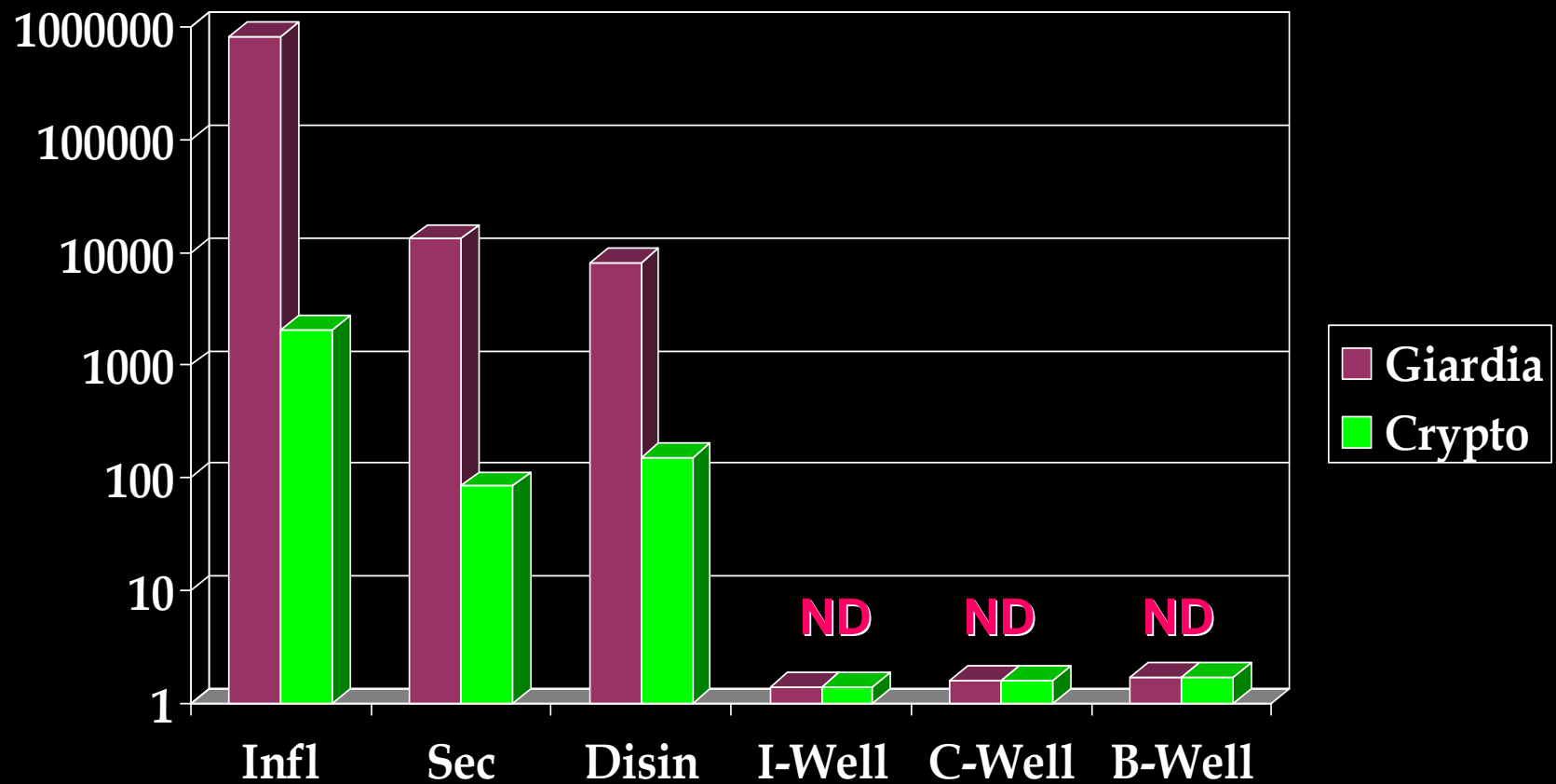
ND = not detected



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# Protozoa (#/100 L)

ND = not detected



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# WERF Study

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# WWTPs in the WERF Study

<b>A</b>	<b>Act Sldg, Fabric Filter, Cl<sub>2</sub></b>
<b>B</b>	<b>Act Sldg, Cl<sub>2</sub>, ABW Filter, Cl<sub>2</sub></b>
<b>C</b>	<b>Act Slgd, Deep Anthracite Filter, Cl<sub>2</sub></b>
<b>D</b>	<b>Act Slgd, Dual Media, Cl<sub>2</sub></b>
<b>E</b>	<b>Nitrif, Dynasand, UV</b>
<b>F</b>	<b>BNR, Dual Media, Cl<sub>2</sub></b>

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# Indicators & Pathogens

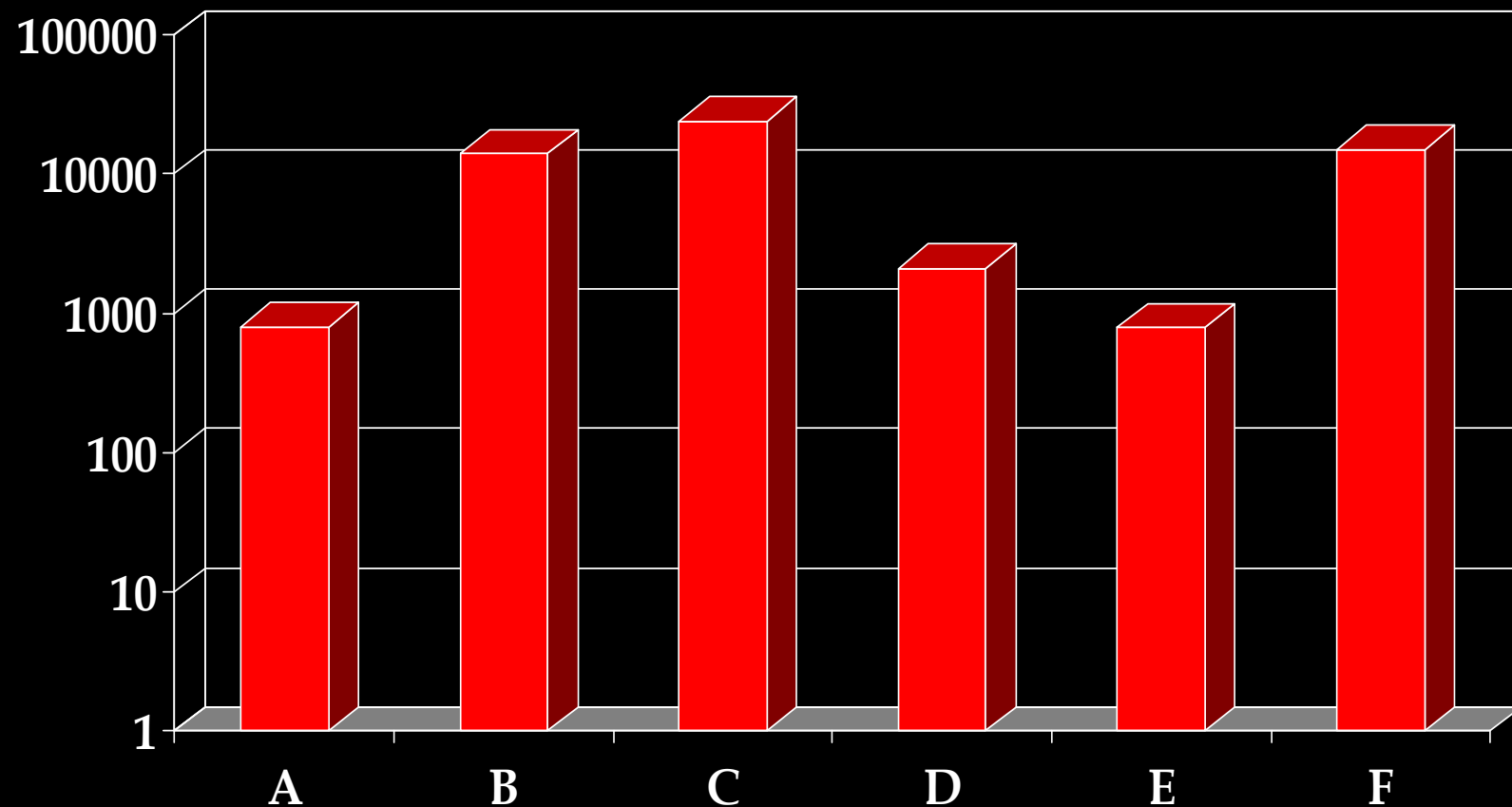
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- **Total Coliforms**
- **Fecal Coliforms**
- **Enterococci**
- **Clostridium**
- **Coliphage – 70089**
- **Coliphage – 15597**

- **Enteroviruses**
- **Giardia**
  - ◆ **Total & DAPI(+)**
- **Cryptosporidium**
  - ◆ **Total & DAPI(+)**
  - ◆ **Viable**

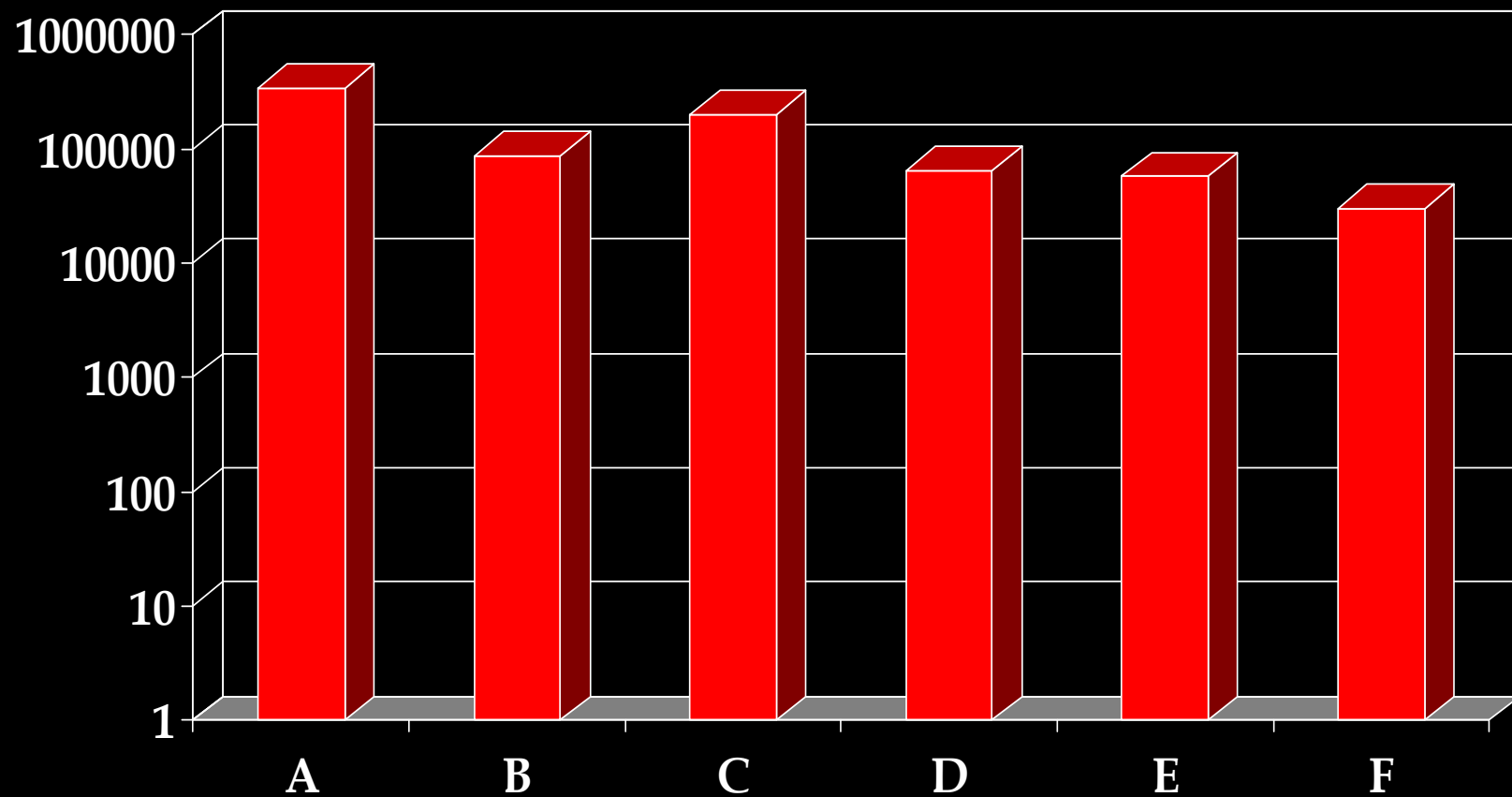
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# Influent Viruses (PFU/100 L)



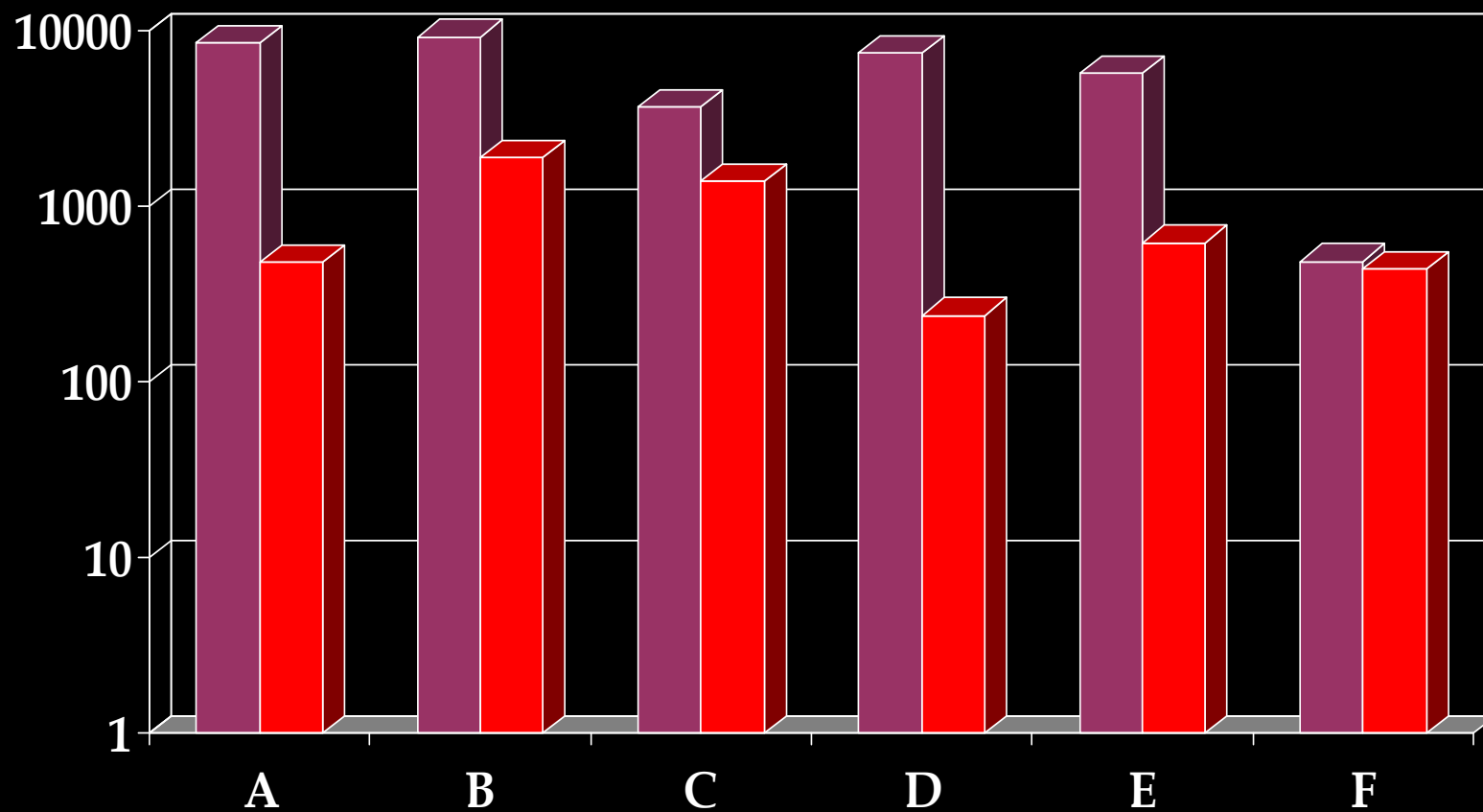
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# Influent Giardia (cysts/100 L)



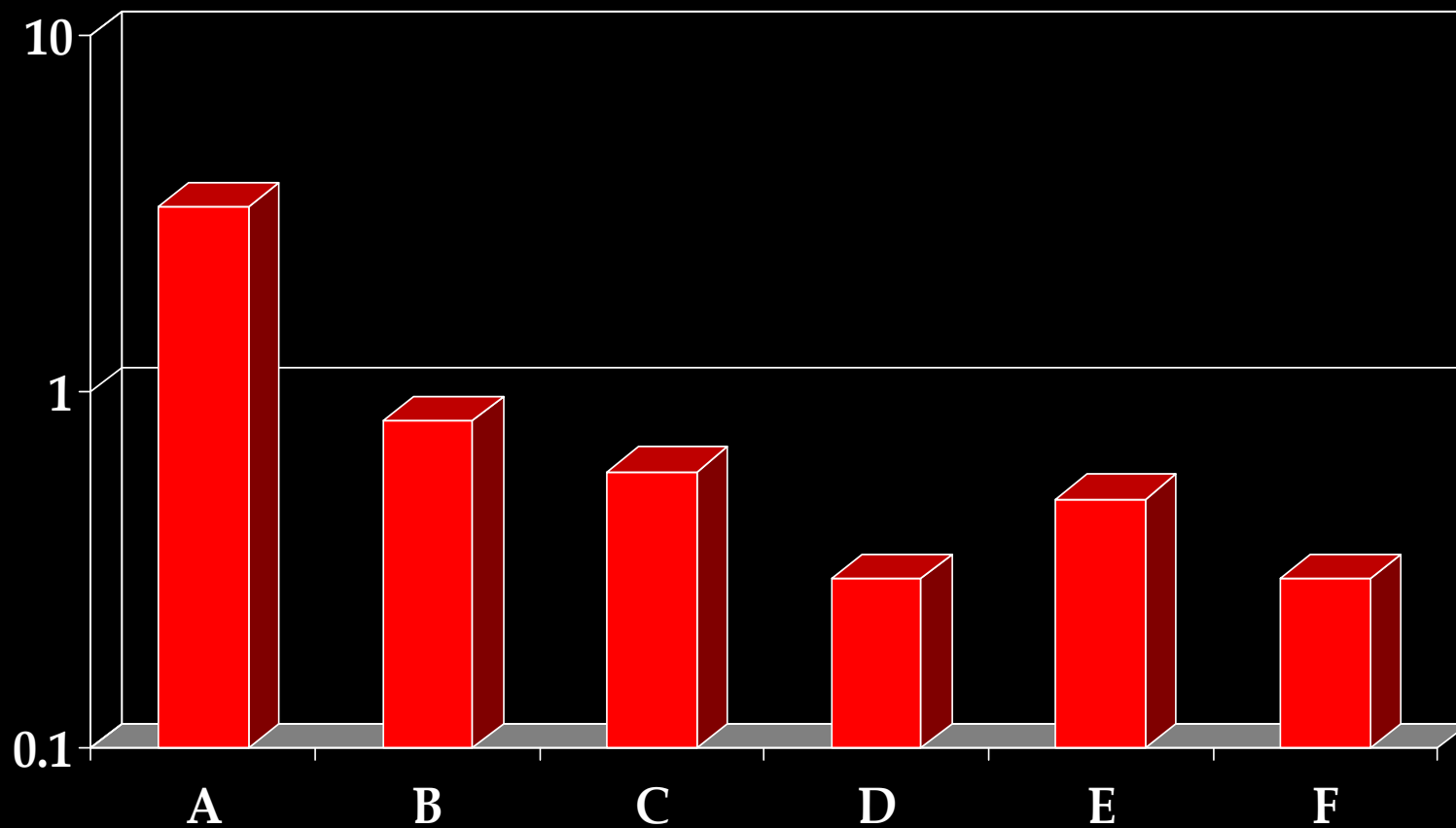
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# Influent Crypto (oocysts/100 L)



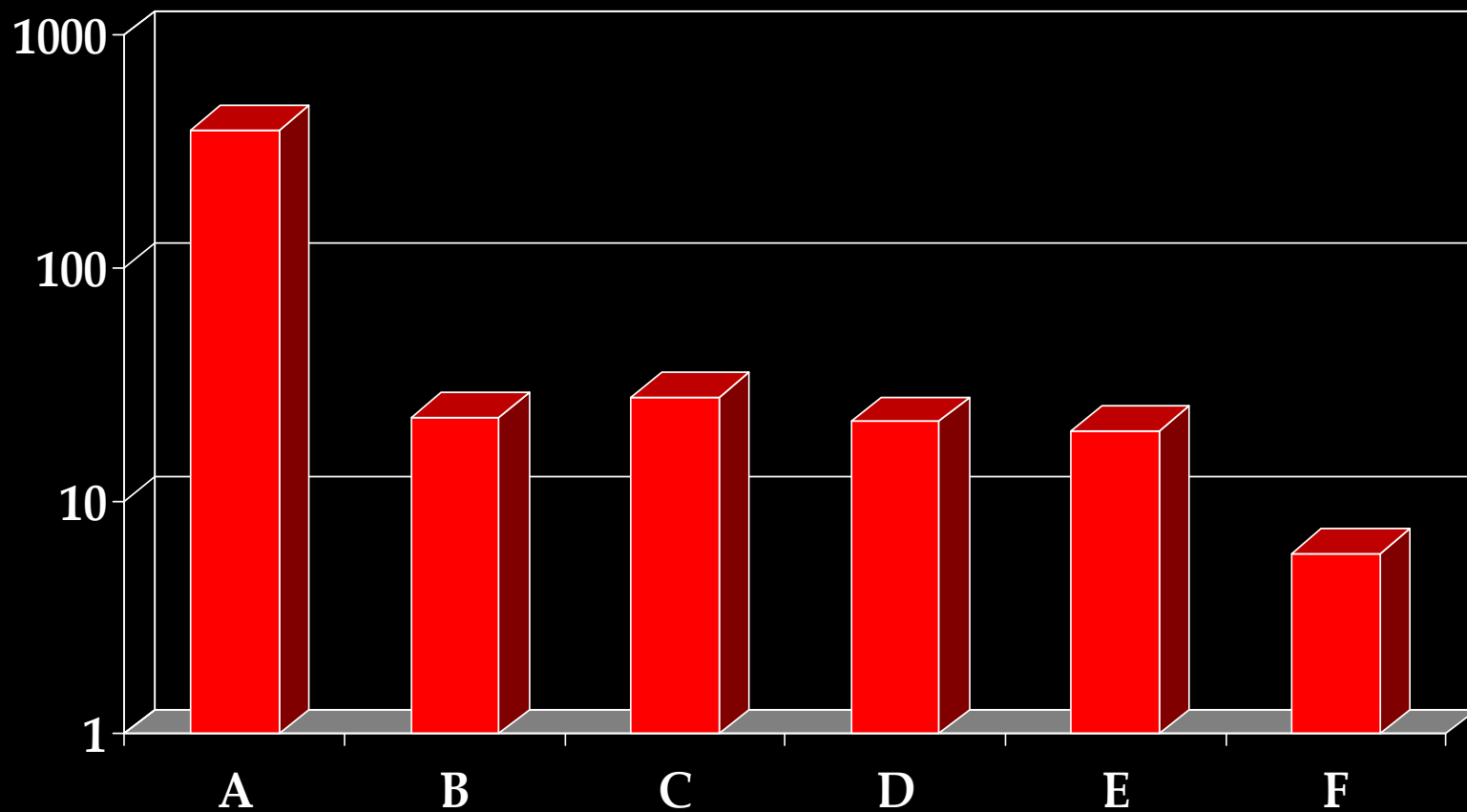
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# Effluent Viruses (PFU/100 L)



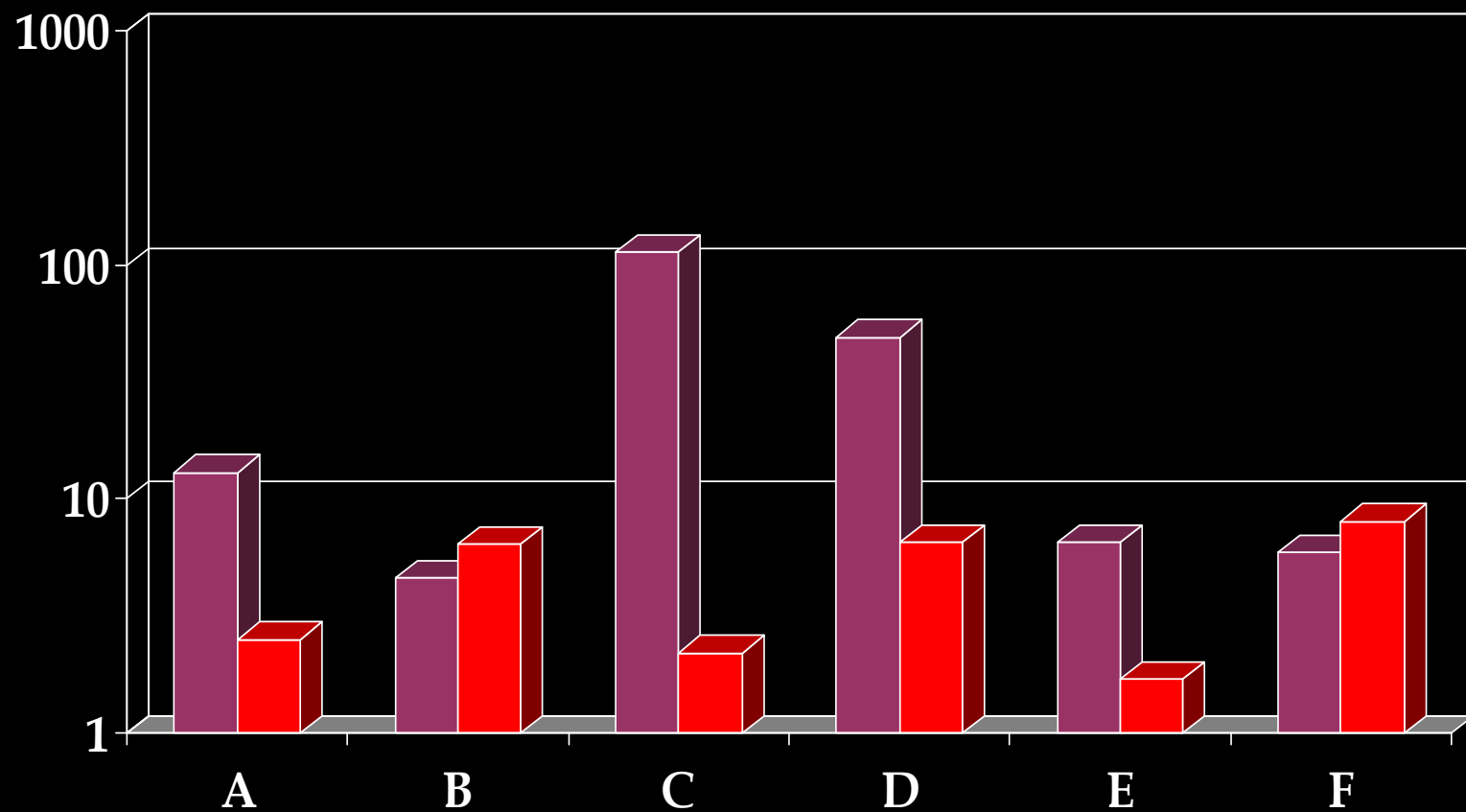
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# Effluent Giardia (cysts/100 L)



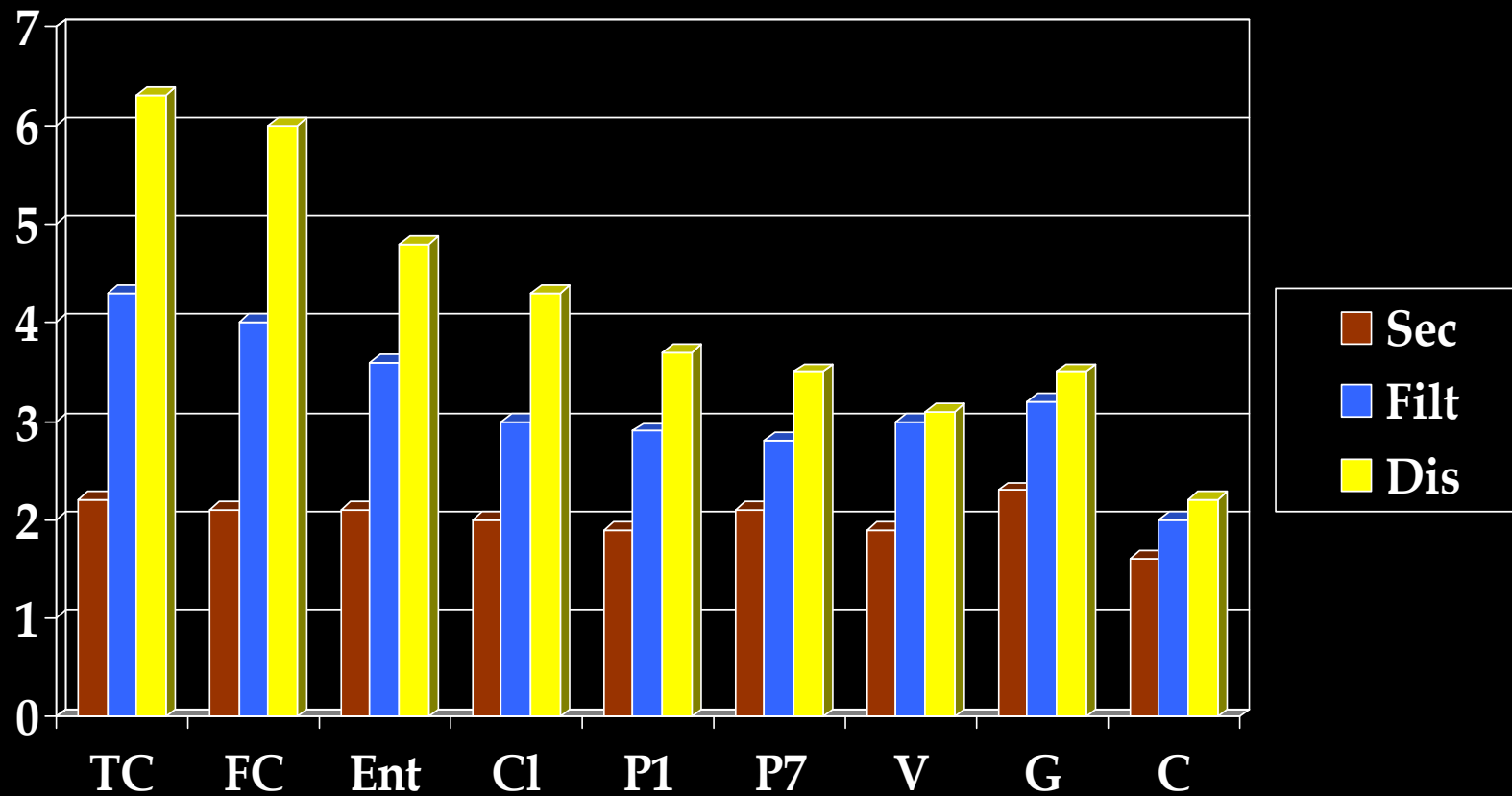
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# Effluent Crypto (oocysts/100 L)



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# Log Removals



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# Observations...

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- **Better Removals with:**
  - ◆ **Higher MLSS**
  - ◆ **Higher MCRT**
  - ◆ **Nitrification**
  - ◆ **Lower Filter Loading**
  - ◆ **Deeper Filters**

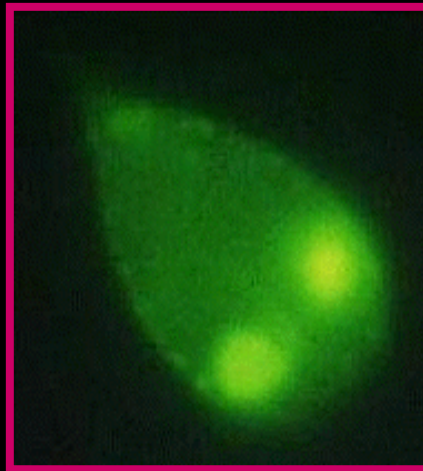
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# Protozoan Pathogens

- **Cryptosporidium**



- **Giardia**



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# Reclaimed Water (# / 100 L)

Statistic	Giardia	Crypto
50 %	3.5	ND
75 %	109	1.7
90 %	352	15
Max.	4,035	352

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No Disease!!!

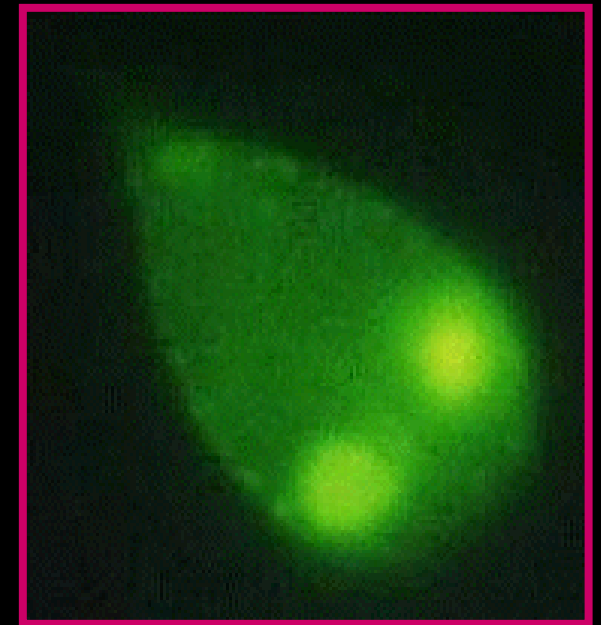
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Are they  
capable of  
causing  
infection?

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# Infectivity Studies

- **Los Angeles County San. District**
  - ◆ **Giardia**
- **Calgary**
  - ◆ **Giardia**
- **Florida**
  - ◆ **Giardia & Crypto**
- **Disinfection Pilot Study**
  - ◆ **Giardia & Crypto**



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# Track Record

# Florida Reuse Facts



- **465 WWTPs**
- **Capacity = 1,325 MGD**
  - ◆ **About 58% of All WWTP Capacity**
- **660 MGD Reused**
  - ◆ **About 41% of All Treated Wastewater**

**2005 Data**

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# Florida Reuse Facts

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- **201,465 Residences**
- **462 Golf Courses**
- **572 Parks**
- **251 Schools**



**2005 Data**

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No Disease!!!

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***Is it Safe?***

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**Yes!!!**

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# Keys to Success

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- **Filtration**
- **Disinfection**
- **State Standards**
- **Cross-Connection Control**

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